What is Junction Breakdown ?

In the *ideal PN junction* device, when a reverse bias voltage is applied, a small reverse bias current flow through the device. This reverse current remains very small until a critical voltage is reached, at which point the current suddenly increases. This sudden increase in current is referred to as the junction breakdown

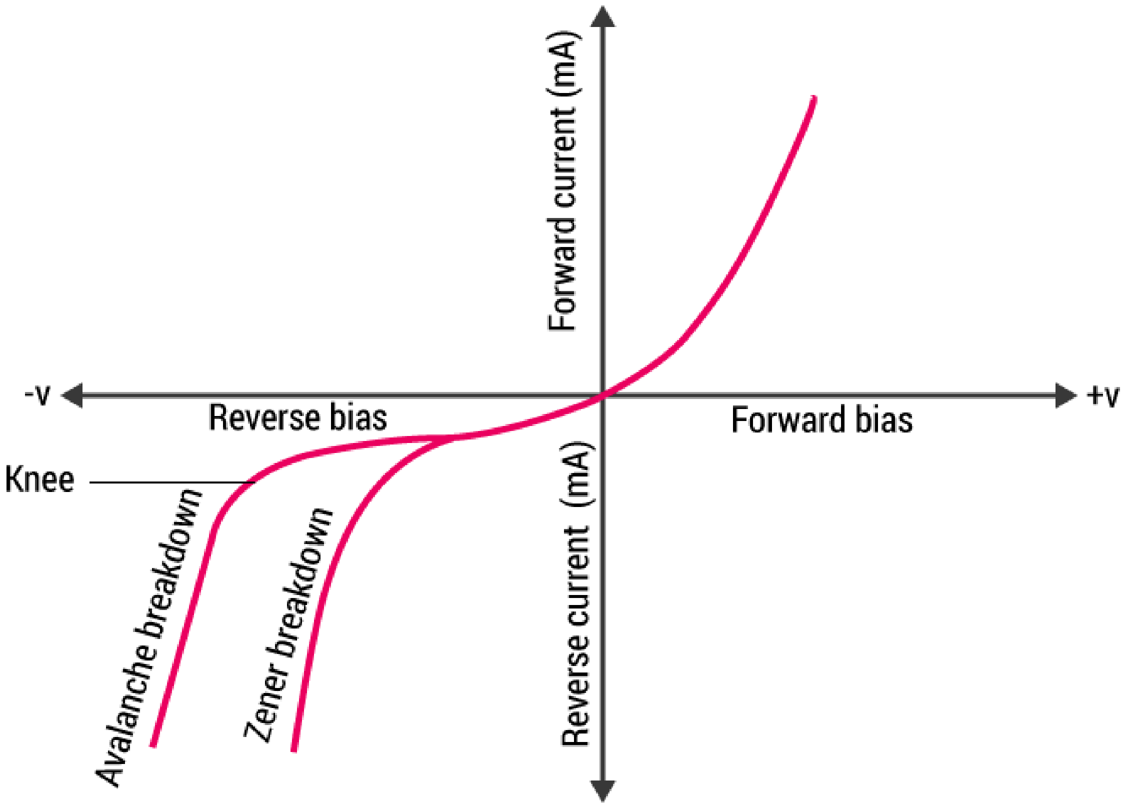
General Breakdown Characteristics

- The maximum reverse bias voltage that can be applied to a p-n diode is limited by breakdown
- Breakdown is characterized by the rapid increase of the current under reverse bias
- The corresponding applied voltage is referred to as the breakdown voltage

Types of Junction Breakdown

There are two physical mechanisms which give rise to the reverse bias breakdown.

- Zener Effect (Zener Breakdown)
- Avalanche Effect (Avalanche Breakdown)



Ideal Diode Equation

- Empirical fit for both the negative and positive I-V of a diode when the magnitude of the applied voltage is reasonably small.

$$I_D = I_S\left(e^{\frac{qV_D}{nkT}} - 1\right)$$

Ideal Diode Equation

Where

I_D and V_D are the diode current and voltage, respectively

q is the charge on the electron

n is the ideality factor: n = 1 for indirect semiconductors (Si, Ge, etc.)
n = 2 for direct semiconductors (GaAs, InP, etc.)

k is Boltzmann's constant

T is temperature in Kelvin

kT/q is also known as V_{th}, the thermal voltage. At 300K (room temperature), kT/q = 25.9mV

Simplification

- When V_D is negative

$$I_D \sim -I_S$$

- When V_D is positive

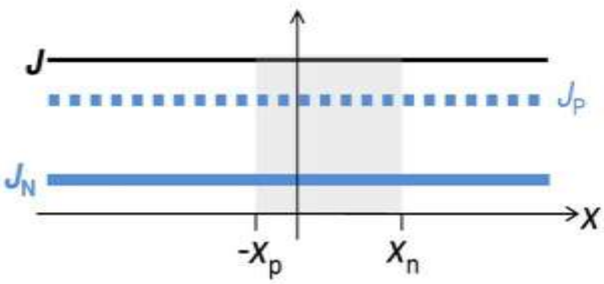
$$I_D \sim I_S e^{\frac{qV_D}{nkT}}$$

General Narrow-Base Diode *I-V*

- Define W_P' and W_N' to be the widths of the quasi-neutral regions.
- **If both sides of a pn junction are narrow** (*i.e.* much shorter than the minority carrier diffusion lengths in the respective regions)**:**

$$I = qAn_i^2\left[\frac{D_P}{W_N' N_D} + \frac{D_N}{W_P' N_A}\right]\left(e^{qV_A/kT} - 1\right) = I_0\left(e^{qV_A/kT} - 1\right)$$

e.g. **if hole injection into the n side is greater than electron injection into the p side:**



Charge Control Model Summary

Under forward bias, minority-carrier charge is stored in the quasi-neutral regions of a pn diode.

– Long base:

$$Q_N = -qA\frac{n_i^2}{N_A}\left(e^{qV_A/kT}-1\right)L_N$$

$$Q_P = qA\frac{n_i^2}{N_D}\left(e^{qV_A/kT}-1\right)L_P$$

– Narrow base:

$$Q_N = -qA\frac{1}{2}\frac{n_i^2}{N_A}\left(e^{qV_A/kT}-1\right)W_P'$$

$$Q_P = qA\frac{1}{2}\frac{n_i^2}{N_D}\left(e^{qV_A/kT}-1\right)W_N'$$